Comparative Analysis of Passive Fit and Time Efficiency in All-on-X Implants Protocols Using Photogrammetry, Splinted Scan Bodies, and Conventional Impression Technique.

تحليل مقارن للملاءمة السلبية والكفاءة الزمنية في بروتوكولات الكل على س من الزرعات باستخدام التصوير القياسى وأجسام المسح المرتبطة والطريقة التقليدية للطبعات.

A proposal submitted to the Faculty of Dentistry – October 6 University in partial fulfillment of the requirements for the Master's degree in Prosthodontics.

By

Mohammed Fathy Abdelhamid

B.D.S, October 6 University, 2020

July 2025

1. Administrative Information

1.1 Roles and Responsibilities

1.1.1 Chief Supervisor: Prof. Dr. Aml Mahmoud Ibrahim (A.M.I)

- Professor of Prosthodontics, Faculty of Dentistry, Cairo University.
- Selection of the study design, supervision on the thesis, and monitoring of data collection.

1.1.2 Co-Supervisor: Dr. Mai Hassan Diab (M.H.D)

- Lecturer in Prosthodontics, Faculty of Dentistry, October 6 University.
- Sequence generation, allocation concealment, randomization, and data management.

1.1.3 Investigator: Mohamed Fathy Abdelhamid (M.F.A)

- Master's degree candidate, teaching assistant, Prosthodontics Department, Faculty of Dentistry, October 6 University.
- Responsibilities: Collection of data, preparation, and conduction of research results.
- Email: mo97.fathy@gmail.com
- Phone: 01099632823

1.1.4 Ethics Committee, Faculty of Dentistry, October 6 University:

It is responsible for:

- Ensuring that the trial does not violate privacy and provides competent review of all ethical aspects of the project.

1.2 Proposal Registration

- The trial will be registered in [ClinicalTrials.gov or another relevant registry].

1.3 Funding: Self-funding.

2. Introduction

2.1. Background and Rationale:

2.1.1. Statement of the Problem:

For edentulous patients undergoing full-arch rehabilitation, the All-on-X rehabilitation approach has gained widespread acceptance. Achieving passive fit of the prosthesis, which has a direct impact on long-term success, requires precise transfer of implant placements from the patient to the lab model. The gold standard for traditional procedures is open tray impressions with pick-up copings. But new developments in digital dentistry have brought other methods including photogrammetry and intraoral scanning using splinted scan bodies.. **(1 &2)**

2.1.2 Rationale for Conducting the Research

For edentulous patients undergoing full-arch rehabilitation, the All-on-X treatment approach has proven to be a very successful option, providing enhanced function, aesthetics, and patient satisfaction. Achieving passive fit, which reduces mechanical stress on implants and prosthetic components and reduces the possibility of problems such screw loosening, fracture, or marginal bone loss, is crucial to the long-term effectiveness of implant-supported prostheses.

Passive fit has traditionally been evaluated after prostheses are fabricated using traditional open-tray impression techniques, which are regarded as the gold standard because of their great precision and dependability. These approaches, however, are challenging, technique-specific, and susceptible to human mistake or material deformation.

Other methods include digital intraoral scanning with splinted scan bodies and photogrammetry have become more appreciated due to the quick development of digital dentistry. Potential advantages of these digital workflows include quicker digital data transfer to the lab, less chairside time,

and improved patient comfort. In the context of the All-on-X procedure, there is still no clinical data comparing the accuracy especially passive fit and time efficiency of these more recent methods with traditional impressions, despite these benefits.

Thus, the purpose of this study is to compare the time efficiency and passive fit of three impression techniques: traditional open-tray impressions, digital intraoral scanning with splinted scan bodies, and photogrammetry. The findings will provide clinicians with evidence-based insights into whether digital alternatives can match or surpass traditional techniques in terms of accuracy and workflow efficiency, ultimately supporting the transition toward more modern, streamlined protocols in implant prosthodontics.

2.1.3 Review of Literature

Jasim et al., 2024 [(3)] "The advent of digital dentistry has significantly transformed clinical protocols in implant dentistry. Intraoral scanning technologies offer notable advantages over conventional impression techniques, including enhanced patient comfort and expedited acquisition of clinical data. However, the accuracy and reliability of intraoral scanners can vary depending on the specific scanning system utilized and the environmental conditions under which the data is captured. "

Zembic et al., 2021 [(4)] "While digital planning and computer-guided surgery have become standard practices in contemporary implant dentistry, the use of digital implant scanning remains a relatively recent advancement within the field. Digital impressions play a pivotal role in integrating the clinical and laboratory stages of the digital workflow for fabricating definitive implant prostheses. Intraoral scanners (IOS) generate digital impressions in the form of Standard Tessellation Language (STL) files, which are subsequently used in the design and production of both interim and definitive implant-supported restorations. Additionally, STL files can be superimposed with data obtained

from cone beam computed tomography (CBCT) or facial scanning systems, enabling the construction of a comprehensive "virtual patient." This integration facilitates more accurate diagnosis, enhanced treatment planning, and improved patient management."

Eldabe et al., 2025 [5] "Photogrammetry is an emerging digital technique that utilizes optical imaging systems to reconstruct three-dimensional models without the need for direct physical contact. This method has demonstrated promising outcomes in terms of accuracy and reproducibility when compared to conventional impression techniques and intraoral scanning. Despite these advancements, the traditional open tray technique continues to serve as the gold standard, owing to its well-established dimensional stability and clinical reliability."

Eid et al., 2024 [6] "The attainment of passive fit in implant-supported screw-retained frameworks is widely regarded as a critical determinant of the functional longevity and clinical success of implant prostheses. Inadequate passive fit has been associated with a range of mechanical complications, including screw loosening, fracture of implant-abutment components, and potential implant failure."

Waldecker et al. (2021) [7] "Time control which involves recording the time taken for each scanning or impression-taking process. In clinical practice, minimizing chairside time not only enhances patient comfort but also improves overall workflow and productivity for dental professionals. By comparing the time required for direct scanning using intraoral scanners versus indirect scanning of conventional impressions, this study aims to provide insights into the practicality and feasibility of digital workflows. Efficient procedures can lead to better patient satisfaction and acceptance. Therefore, assessing time control complements the primary outcome of accuracy, offering a more comprehensive evaluation of the methods under investigation.

2.1.4 Explanation for Choice of Comparators

Traditional open tray impressions are regarded as the gold standard because of their passivity and consistency in relaying various implant sites. In this study, they function as the control group for comparing the accuracy of modern digital technologies, specifically photogrammetry and digital scanning using splinted scan bodies. This facilitates the easy assessment of whether digital alternatives provide equivalent or greater results[5].

2.2 Objectives

PICOT

- **(P) Population:** Patients requiring a full-arch maxillary implant-supported fixed prosthesis (All-on-X concept).
- **(I) Intervention**:

Digital intraoral scanning using splinted scan bodies and photogrammetry for implant position transfer.

- **(C) Comparator:** Conventional implant-level open tray impression technique using pick-up copings (gold standard).
- **(O) Outcomes:**

- Primary Outcome: Passive fit of the implant-supported framework, measured as vertical marginal gap (in µm) at implant-abutment interfaces using 3D inspection software (Geomagic Control X)
- Secondary Outcome: Time efficiency of each impression-taking workflow, measured as the total clinical time required to complete the procedure from screwing the impression coping/scan body to final scan/impression verification.

(T) Time: Evaluation of outcomes will be performed immediately after exposure of the implants and during impression procedures for fabrication of the final prosthesis.

2.3 Trial Design

In Vivo Clinical Study This is an interventional, three-arm comparative clinical trial with a crossover design .

2.4 Research Question (Focused Question):

Does the use of photogrammetry and digital intraoral scanning with splinted scan bodies provide comparable or improved accuracy in implant position transfer as measured by passive fit and time efficiency when compared to the conventional open-tray impression technique in the All-on-X treatment concept?

3. Materials and Methods

3.1 Participants, Materials, Interventions & Outcomes

3.1.1 Eligibility Criteria:

3.1.2.1. The Inclusion Criteria:

1- Age: Adults aged between 45 and 65 years.

2- Edentulism: Fully edentulous or partially edentulous maxilla requiring full-arch rehabilitation.

3- Bone Availability: Sufficient bone volume in the maxilla to support at least four implants according to the All-on-X.

4- General Health Status: Systemically healthy patients with no contraindications to dental implant surgery (ASA I–II classification).

5- Oral Hygiene: Demonstrated ability to maintain adequate oral hygiene.

6- Patient Motivation: Willingness to participate in the study and comply with follow-up visits and required maintenance protocols.

7- Prosthetic Need: Patients seeking a fixed, implant-supported prosthesis for the maxilla due to missing teeth and inability to use removable prostheses effectively.

8- Radiographic Evaluation: Acceptable radiographic findings showing no signs of pathology, infection, or significant anatomical limitations.

3.1.2.2. The Exclusion Criteria:

1- Medical Conditions:

- Uncontrolled systemic diseases such as diabetes mellitus, osteoporosis, or immunosuppressive disorders.
- History of radiation therapy to the head and neck region.

2- Oral Conditions:

- Active periodontal disease or untreated caries.
- Presence of cysts, tumors, or other pathologies affecting the maxilla.
- Poor oral hygiene or inability to cooperate with post-operative care.

3- Anatomical Limitations:

- Insufficient bone volume to place at least four implants without extensive grafting procedures.
- Maxillary sinus pathology or oroantral fistulas.
- Psychological or Behavioral Factors:
- Psychiatric illness or cognitive impairment that may interfere with treatment compliance.
- Bruxism or parafunctional habits confirmed by clinical evaluation or patient history.

4- Pregnancy:

- Pregnant or lactating women (due to potential risks related to surgical intervention and radiographic exposure).

5- Implant Contraindications:

- History of previous implant failure or allergy to titanium.
- Current use of bisphosphonates or antiresorptive medications associated with jaw osteonecrosis.

6- Smoking Habits: Heavy smokers (>10 cigarettes/day) considered a relative contraindication due to compromised healing and increased implant failure rates.

7- Compliance Issues: Patients unwilling or unable to attend scheduled follow-up appointments or adhere to postoperative instructions.

8- Temporomandibular Joint Disorders (TMD):

Patients with a diagnosed or symptomatic temporomandibular joint disorder (e.g., pain, clicking, locking, limited mouth opening, or muscle tenderness) will be excluded from the study. TMD can affect mandibular stability, occlusal accuracy, and jaw positioning during scanning or impression procedures, which may introduce errors in data capture and compromise the reliability of marginal and internal fit measurements.

3.1.2 Materials:

1- Implants: Implants will be placed according to the All-on-X concept.

2- Healing Abutments: Temporary healing caps used during osseointegration phase.

3- Multi-unit Abutments: Angled abutments (0°, 17°, 30°) used to correct angulation discrepancies for prosthetic rehabilitation.

4- Implant-Level Pick-up Impression Copings: stock impression copings designed to fit directly onto implant analogs.

5- Open Tray System: Metal or plastic trays with access holes for screwing down impression copings.

6- Polyvinyl Siloxane (PVS) Impression Material: Heavy-bodied PVS for tray stabilization and Light-bodied PVS for fine detail reproduction around impression copings.

7- Digital Scanning Components

- Splinted Scan Bodies: Scan bodies designed to be screwed onto multi-unit abutments for accurate intraoral scanning. Splinting bar to connect scan bodies and enhance spatial stability.
- Intraoral Scanner (IOS): For direct scanning splinted scan bodies and photogrammetry.
- Desktop Optical Scanner: For scanning conventional impressions and stone casts.

8- Photogrammetry Equipment: Intraoral photogrammetry scanner (IPS) for complete arch implant-supported prostheses.

9- Master Model and Analog System:

- Maxillary Acrylic Resin Printed Master Model which fabricated to simulate the All-on-X implant configuration.
- Implant Analogues: Accurate replicas of the selected implant system embedded into the master model for testing purposes.

10- CAD/CAM Software and Hardware

- CAD Software: will be used for designing the prosthesis and superimposing scans for accuracy analysis.
- CAM Milling Machine: For fabricating frameworks from digital data.
- 3D Inspection Software: For measuring trueness and precision using RMS deviation (Geomagic Control X).

11- Stop Watch: Will be used for calculate the time in seconds.

3.1.4. Interventions:

3.1.4.1. Procedures:

A- Preoperative Planning

- Cone-beam computed tomography (CBCT) scans and intraoral scans will be used for virtual treatment planning.
- A surgical guided stent will be fabricated using CAD/CAM technology to ensure accurate placement of implants according to the All-on-X concept.
- The guided stent ensures optimal implant angulation, depth, and inter-implant distances to facilitate prosthetic rehabilitation.

B- Implant Surgery

- Guided surgery will be performed under local anesthesia using the pre-fabricated surgical guide.
- Implants will be placed following the All-on-X protocol.
- Immediate postoperative radiographs will be taken to confirm implant position and integration.

C- Healing Period

- Patients will undergo a healing period of 4–6 months to allow for complete osseointegration.
- During this time, patients will wear a removable provisional prosthesis.
- Post-healing, patients will return for impression-taking procedures.

D- Impression/Scanning Techniques:

After the healing phase, each patient will undergo all three impression techniques in a crossover design, meaning each participant serves as their own control across the three interventions. Randomization will determine the sequence of interventions.

Group I: Conventional Open Tray Impression Technique (Control Group) Procedure:

- Custom trays will be fabricated for each patient, Pick-up impression copings will be screwed onto the implants. Splinting of the impression coping will be done. Polyvinyl siloxane (PVS) impression material will be loaded into the tray. Light-bodied PVS will be syringed around the impression copings. The tray will be seated carefully and allowed to set.
- After setting, impressions will be poured with Type IV dental stone to fabricate master casts. Master casts will be scanned using a desktop scanner to generate digital models.

Group II: Digital Intraoral Scanning with Splinted Scan Bodies (Comparator 1) Procedure:

- Splinted scan bodies will be screwed onto the implants.
- Intraoral scanning will be performed using Intraoral Scanner
- Digital data will be exported as an STL file.
- Direct digital model of implant positions captured intraorally.

Group III: Photogrammetry technology (Comparator 2) Procedure:

- Photogrammetry scan bodies will be fixed on the implants. High-resolution images will be captured from multiple angles. 3D reconstruction software will be used to create a digital model based on image triangulation.
- Data will be exported as an STL file.
- Digital model of implant positions generated via photogrammetry.

E- Common Steps for All Groups:

After obtaining digital impressions using the three different techniques (conventional open-tray, intraoral scanning with splinted scan bodies, and photogrammetry), the following standardized steps will be performed for all participants:

1. Digital Framework Design

The STL files obtained from each impression technique will be used into CAD software . A screw-retained implant-supported framework will be digitally designed to match the planned prosthetic rehabilitation. The design will ensure proper occlusion, anatomy, and passive seating on the master model.

2. Framework Fabrication

The designed framework will be milled from a cobalt-chromium (Co-Cr) alloy block using a CAM milling machine . Each framework will be clearly labeled according to the impression technique used.

3. Framework Scanning (Individual Scan)

Each fabricated framework will be scanned individually using a high-resolution desktop optical scanner . This will generate a digital STL model of the framework alone .

4. Framework Seating and Model Scanning

The framework will then be passively seated onto its corresponding master cast or digital model derived from the impression technique. The framework-cast

assembly will be scanned again using the desktop scanner to capture the spatial relationship between the framework and implant positions.

5. 3D Superimposition and Passive Fit Evaluation

Using 3D inspection software (e.g., Geomagic Control X) , the individual framework scan will be superimposed onto the scan of the framework seated on the cast. Deviations at the implant-framework interface will be analyzed quantitatively. The vertical marginal gap will be measured at each implant site to assess the degree of misfit. Measurements will be expressed in micrometers (μm) and averaged across all implants per framework.

6. Complete the steps for construction of the passivly fit final prosthesis which will be screwed on the patient mouth.

3.1.4.2. Intervention group:

- Group II: Direct scanning with intraoral scanner and splinted scan bodies
- Group III: Photogrammetry technology.

3.1.4.3. Control group:

- Group I: Conventional implant level open tray impression technique → indirect scanning

3.1.4.4. Outcomes:

- Primary Outcome: Passive fit measured using 3D inspection software (Geomagic Control X).
- Secondary Outcome: Time efficiency, assessed using stop watch and measured by seconds.

3.1.5 Sample Size Calculation:

Sample size calculation was performed using G*Power version 3.1.9.7 based on the results of a previous study ***(Eid et al., 2024)*** [6] **.** A power

analysis was designed to have adequate power to apply a two-sided statistical test to reject the null hypothesis that there is no difference between groups. By adopting an alpha level of (0.05) and a beta of (0.1), i.e. power = 90% and an effect size (d) of (0.41867923) calculated based on the results of a previous study. The predicted sample size (n) was (14 sample). The passive fit in implant prosthodontics through three digital impression techniques "conventional impression, intraoral scanning, and photogrammetry" will be evaluated and statistically compared.

3.2 Assignment of Interventions:

3.2.1 Allocation:

- Allocation Ratio: 1:1:1.

3.2.1.1. Randomization:

Block randomization performed by the chief supervisor.

3.2.1.2. Allocation concealment mechanism:

The allocation sequence will be kept with the co-supervisor concealed from the primary investigator.

3.2.1.3. Implementation:

The chief supervisor is the person who will generate the allocation sequence centrally and who is responsible for ensuring proper randomization and allocation concealment.

3.2.2. Blinding:

Single-blinded study.

3.3. Data collection, management, and analysis:

3.3.1. Data collection methods:

No data collection.

3.3.2. Data management:

Data entry by excel office 2016. The data entry will be on my own.

3.3.3 Statistical Analysis:

The collected data will be, tabulated, and statistically analyzed using SPSS program (Statistical Package for Social Sciences) software version 23.0. Normality will be explored using the Kolmogorov-Smirnov and Shapiro-Wilk Test.

Descriptive statistics will be done for numerical parametric data as mean±SD (standard deviation) and minimum & maximum of the range and for numerical non parametric data as median and 1st& 3rd inter-quartile range, while it will be done for categorical data as number and percentage.

Inferential analyses will be done for quantitative variables using Repeated measures ANOVA tests for whether there are any differences between related means, Post hock comparisons using Bonferroni correction.

Inferential analyses will be done for qualitative data using Chi square test for independent groups. The level of significance will be taken at P value <0.050 is significant, otherwise is non-significant. The p-value is a statistical measure for the probability that the results that will be observed in a study could have occurred by chance [8&9].

3.4. Monitoring:

3.4.1. Data monitoring:

There is no data monitoring committee for this trial.

3.4.2. Harms:

Expectancy of inaccuracies in scan data leading to misfit prostheses, which could lead to fracture and compromise the restoration's longevity and success.

3.4.3. Auditing:

Auditing will be done by the main and co-supervisors to assure quality of the research methods and interventions.

4. Ethics and dissemination

4.1. Research ethics approval:

I am planning for seeking the research ethics approval from Faculty of Dentistry, October 6 University, Research Ethics Committee.

4.2. Declaration of interest:

There is no financial or other personal interest of any nature or kind in any product service.

4.3. Access to data:

I will finalize the trial dataset in adequate statement.

5. Appendices

5. 1. Informed consent form:

There will be an informed consent collected from the patients.

6. References:

1. Drancourt, N., Auduc, C., Mouget, A., Mouminoux, J., Auroy, P., Veyrune, J. L., El Osta, N., & Nicolas, E. (2023). Accuracy of Conventional and Digital Impressions for Full-Arch Implant-Supported Prostheses: An In Vitro Study. Journal of personalized medicine, 13(5), 832.

2. Papaspyridakos, P., Souza, A., Finkelman, M., Sicilia, E., Gotsis, S., Chen, Y.-W., Vazouras, K., & Chochlidakis, K. (2022). Digital vs conventional full-arch implant impressions: A retrospective analysis of 36 edentulous jaws. Journal of Prosthodontics, 32 (1), 45–51.

3. Jasim, A. G., Abo Elezz, M. G., Altonbary, G. Y., & Elsyad, M. A. (2024). Accuracy of digital and conventional implant-level impression techniques for maxillary full-arch screw-retained prosthesis: A crossover randomized trial. Clinical implant dentistry and related research, 26(4), 714–723.

4. Zembic, A., Müller, P., Nahles, S., & Filippi, A. (2021). Digital vs conventional implant impressions in partially and fully edentulous patients: A systematic review. The International Journal of Oral & Maxillofacial Implants, 36 (2), 341–352.

5. Eldabe, A. K., Adel-Khattab, D., & Botros, K. H. (2025). Accuracy of intraoral photogrammetry in complete arch digital implant scanning: An in vivo prospective comparative study. The Journal of Prosthetic Dentistry, S0022-3913(25)00294-X. Advance online publication.

6. Eid, H. S., Zohdy, M. M., Nour, M., & Salah, T. (2024). A comparative analysis of the passivity of fit of complete arch implant-supported frameworks fabricated using different acquisition techniques. The Journal of Prosthetic Dentistry, 131(3), 477-e1.

7. Waldecker, M., Rues, S., Rammelsberg, P., & Bömicke, W. (2021). Accuracy of complete-arch intraoral scans based on confocal microscopy versus optical triangulation: A comparative in vitro study. The Journal of prosthetic dentistry, 126(3), 414–420.

8. Faul, F., Erdfelder, E., Lang, A., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behavior Research Methods, 39(2), 175-191.